An Investigation of Micro-Debris in Plankton Samples Collected during NOAA Surveys in the Southeast Bering Sea and off the U.S. West Coast, 2006-2007, with special attention to Plastic Particles.

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Background

Experts recognize that plastic debris are present in the ocean and can cause harm to wildlife by ingestion and entanglement. However, further scientific research is needed for a comprehensive understanding of the nature and impact of plastic debris in marine ecosystems. In particular, little is known about the impact of small plastic debris particles (millimeters and less size range) throughout the pelagic zone of the world's oceans, especially their potential interaction with planktonic organisms in productive coastal ecosystems. To further understand this issue, a pilot study was developed as part of the National Oceanic and Atmospheric Administration's (NOAA) ongoing ecosystem surveys in the Northeast Pacific Ocean. Funding for this study was provided by NOAA's Marine Debris Program (through the National Fish and Wildlife Foundation), together with matching funds from the American Chemistry Council. The purpose of this study was to document the occurrence and abundance of debris particles in plankton samples, with special emphasis on plastic, in survey areas in the Southeast Bering Sea and off southern California, and to contribute to the development of a standardized protocol for future research into the incidence and effect of small particles of plastic debris in ocean ecosystems.

Plankton Sampling and Debris Analysis

Plankton sampling was carried out in collaboration with NOAA's Alaska Fisheries Science Center in Seattle, Washington, and Southwest Fisheries Science Center in La Jolla, California. These Northeast Pacific research programs include the Ecosystem and Fisheries Oceanography Investigations (EcoFOCI) program in Alaska waters, and the California Cooperative Oceanic and Fisheries Investigations (CalCOFI) program off the U.S. West Coast, primarily off California. Zooplankton samples were collected, as time and primary sampling programs allowed, during two EcoFOCI cruises in the Southeast Bering Sea in the spring and fall of 2006, and during four CalCOFI cruises off the U.S. West Coast in spring, summer and fall of 2006, and in January of 2007. Surface zooplankton (neuston) samples were collected during all cruises whereas sub-surface samples were collected during the CalCOFI cruises only. Collection of zooplankton by towed nets and subsequent laboratory analysis were conducted using standard research protocols implemented by the NOAA Ecosystem Survey Programs. A total of 593 plankton samples from these research cruises were processed for debris particles. All inorganic debris particles were removed from each plankton sample, and the individual debris samples were sent for analysis to an independent analytical laboratory, Impact Analytical in Michigan (www.impactanalytical.com), for identification and evaluation. Zooplankton measurements (dry mass, converted from wet displacement volume) and debris particle quantity and mass (plastic and non-plastic fractions) were standardized to units per cubic meter of seawater for each sampling station.

Results and Conclusions

Results from this study indicate that tiny amounts of debris, including plastic particles, are present primarily in surface waters of the Southeast Bering Sea and California Current coastal ecosystems. The total mass of non-plastic debris particles from all samples and cruises combined was 2.37 grams, while the mass of plastic particles was 1.45 grams. For this study, the non-plastic components (primarily paint chips and metal fragments) of the debris data are considered a qualitative rather than a quantitative representation of the occurrence of such particles in the areas surveyed because of possible contamination from the hull and superstructure of the research vessels during sampling. The mean standardized quantity of plastic debris, expressed as mass (mg) and numbers of particles per meter

cubed, was very low overall for both sampling areas and all cruises (<1 mg/ m^3, and <0.2 particles/m^3, respectively) but spatial and temporal variability was apparent within the range of values recorded (Fig.1). The plastic particles were further analyzed and assigned into three plastic product types: product fragments, fishing net and line fibers, and industrial pellets; and five size categories: <1 mm, 1-2.5 mm, 2.5-5 mm, 5-10 mm, and >10 mm. These data show that product fragments accounted for the majority of the particles in the plankton samples, and that most of these fragments were less than 2.5 mm in size (Figs. 1 and 2). Although the quantity of plastic particles was extremely low, their ubiquity in the plankton samples (occurred in 9 - 83% of samples among cruises), along with the high proportion of particles <2.5 mm, implies persistence in these pelagic ecosystems as a result of continuous break down from larger plastic debris fragments, and widespread distribution by ocean currents. Seasonal variation in abundance of micro-debris particles was observed in both regions and is likely related to seasonal variation in meteorological and oceanographic conditions. Distribution patterns observed in the CalCOFI sampling region give us some indication of potential sources and transport of plastic particles in the California Current Ecosystem. The consistent association of highest mass of plastic particles with the southern-most coastal stations of the sampling grid reflects the likely impact of debris input from the most industrialized urban area of the California Coast, in particular the Los Angeles river basins. During the summer and autumn cruises, the highest levels of plastic debris were also observed at the outermost sampling stations in the grid suggesting that the southerly flowing California Current may be an oceanic source of plastic debris particles that originated in the North Pacific Central Gyre.

For each of the sampling cruises, the estimated biomass of zooplankton was many orders of magnitude higher (mean cruise values of 15-49 mg/m^3 for the surface samples, and 37-189 mg/m^3 for the sub-surface samples) than the mass of plastic debris particles (<1 mg/m^3), both for average cruise values and among individual samples. The low mass and concentration of plastic particles relative to the zooplankton, in the surface layer and throughout the water column, implies minimal interaction with, and impact on, the prevailing zooplankton communities in the two sampling regions. Even though it may be theoretically possible for some of the large zooplankton organisms to ingest these small plastic particles, the likelihood of ingestion also depends on encounter rates (which are likely extremely low), and prey niche and feeding behavior of the specific organisms of interest.

Recommendations

1. Develop new research programs to study the impact of plastic in the ocean environment through collaboration between NOAA's Marine Debris and NOAA Ecosystem Research Programs.

2. Determine the degradation process and end products of plastic debris in the marine environment to better understand the potential ecological impacts of these particles which have been broken down by environmental exposure.

3. Perform a quantitative assessment of plastic particle and zooplankton species encounter rates, especially in the neuston (surface plankton), in order to understand the ingestion potential

4. Investigate the seasonal dynamics of marine debris in relation to seasonal variation in the meteorological and oceanographic environment and at different spatial scales in the ecosystem of interest, in order to understand the temporal and spatial variability in potential impact of the plastic debris on marine organisms.

5. Determine if ongoing trophic studies that investigate feeding habits and prey niches among the larger marine planktonic organisms could be utilized for information on the incidence of plastic ingestion. For example, stomach content analysis of certain species of marine fish larvae is routine in many fisheries laboratories and may provide useful information on the potential ingestion of debris particles by these organisms.

6. Conduct research on the absorption, adsorption, and release of chemicals by plastic and other debris particles in the marine environment. Toxicology studies on marine zooplankton are necessary in order

to investigate the possibility of uptake of toxins from plastic or other inorganic debris particles in marine ecosystems.

7. Determine if non-plastic debris is specific to the research vessel or generally present in coastal waters.

Summary

1. From analysis of 593 samples taken over a year in the SE Bering Sea and off the coast of southern California, it was determined that plastic and non-plastic debris particles are present in coastal waters, albeit at extremely low levels (sample average of less than 1 milligram [.000035 ounce] per cubic meter of water).

2. The most common sources of plastic particle debris are containers and other plastic products.

3. Zooplankton biomass was many orders of magnitude greater than the mass of debris particles for both individual samples and research cruise averages.

4. Almost all debris particles were found in the neuston (surface) layer of the ocean.

5. Sub-surface debris particles were found only in the January 07 cruise samples – a very small number of relatively large particles – possibly due to ocean turbulence.

6. The likelihood of ingestion is minimal due to the low mass and concentration of debris particles relative to zooplankton organisms.

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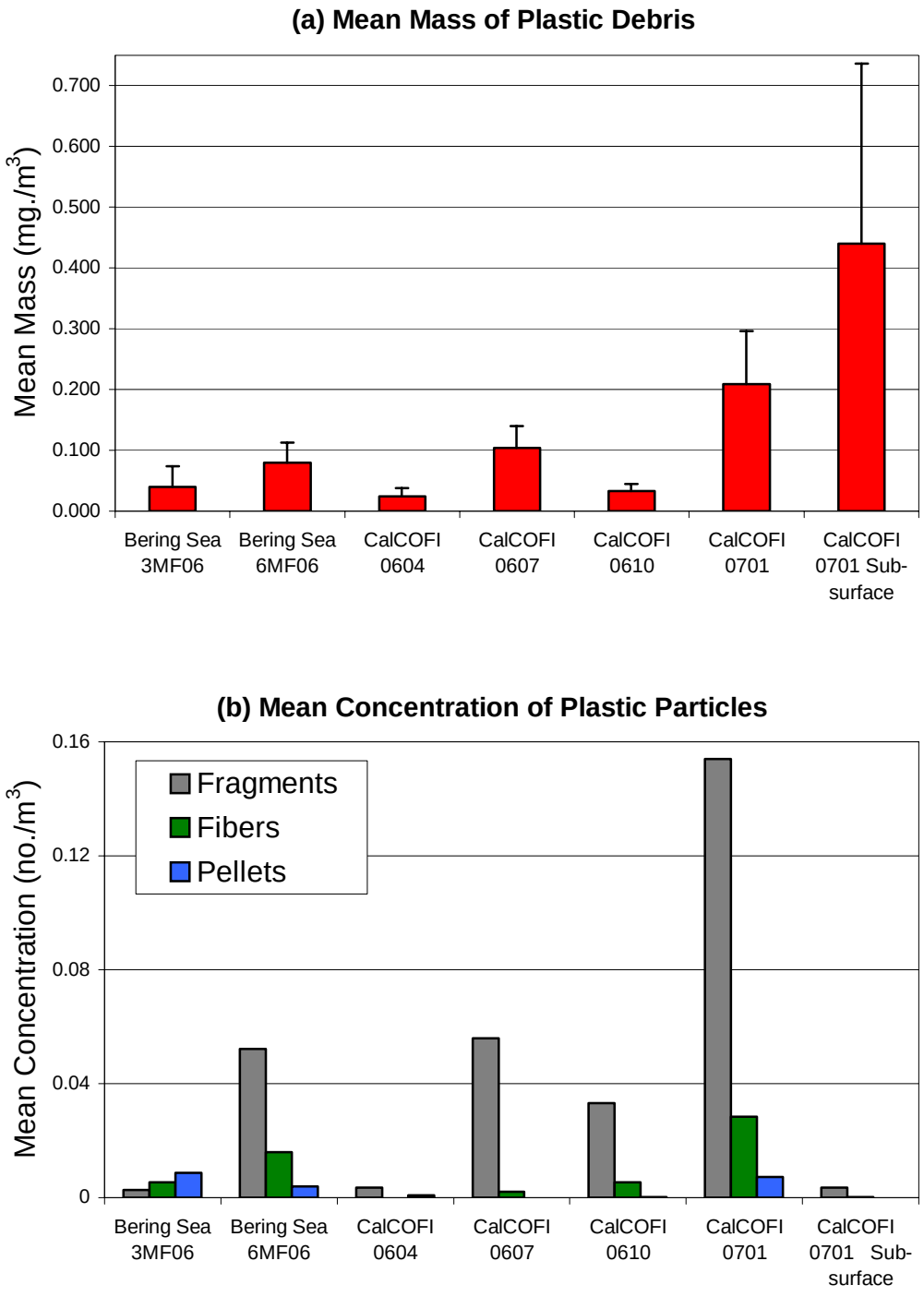

Figure 1.
Mean and standard error of mass (a), and mean concentration (b) of plastic debris particles, by type, among surface samples from all research cruises, and among sub-surface samples from the winter CalCOFI cruise 0701.

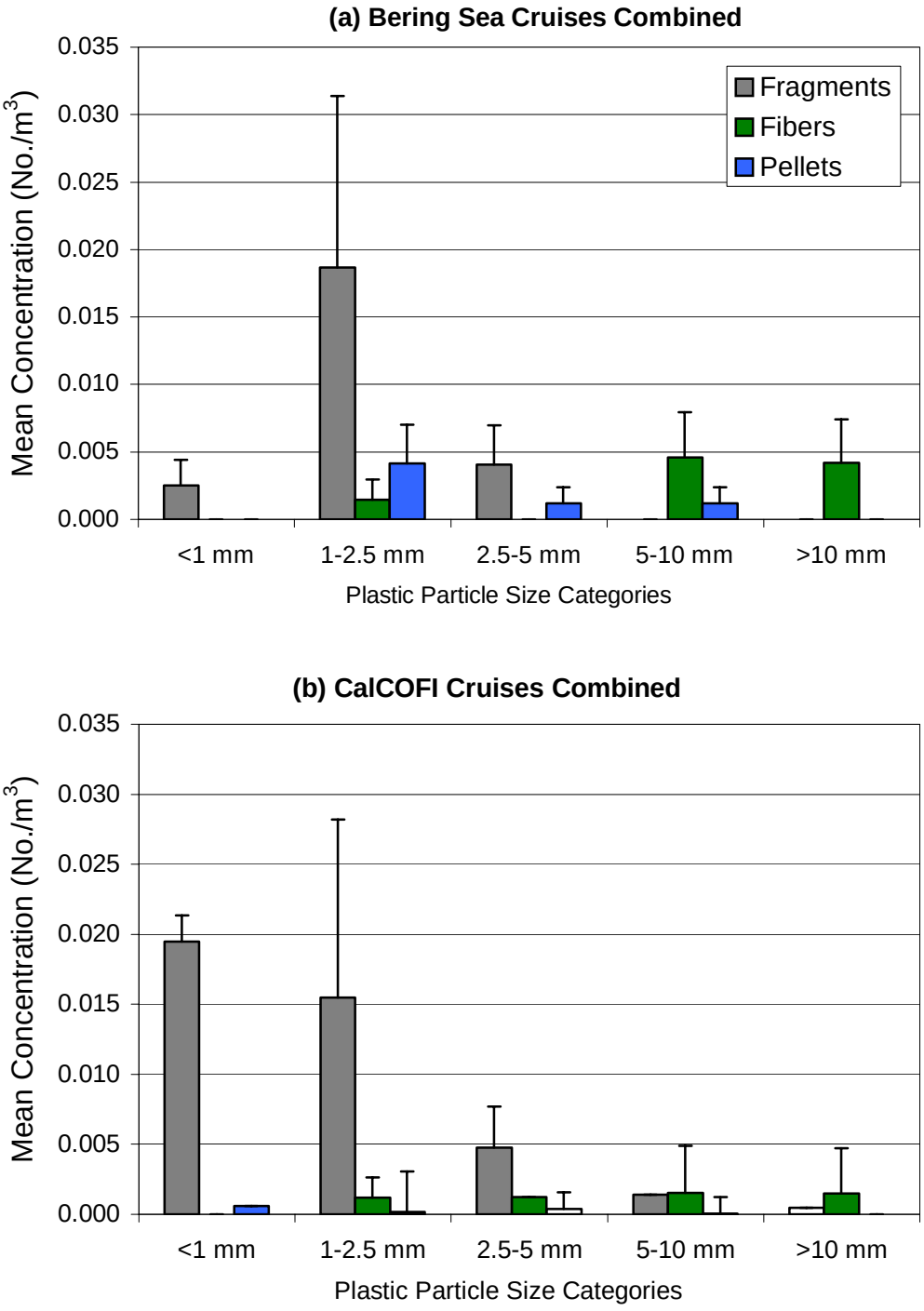

Figure 2.
Mean and standard error of concentration of plastic particles among five size categories in samples combined from (a) Bering Sea cruises, and (b) CalCOFI cruises.